CHAPTER

1.9

MAGNETICALLY COUPLED CIRCUITS

Statement for Q.1-2:

In the circuit of fig. P1.9.1-2 $i_1 = 4\sin 2t$ A, and $i_2 = 0$.

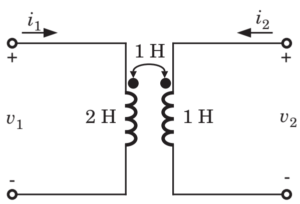

Fig. P1.9.1-2

1. v_1 = ?

(A) $-16\cos 2t$ V (B) $16\cos 2t$ V

(C) $4\cos 2t$ V (D) $-4\cos 2t$ V

2. v_2 = ?

(A) $2\cos 2t$ V (B) $-2\cos 2t$ V

(C) $8\cos 2t$ V (D) $-8\cos 2t$ V

Statement for Q.3-4:

Consider the circuit shown in Fig. P1.9.3-4

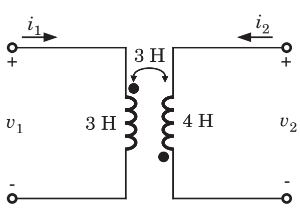

Fig. P1.9.5-6

3. If $i_1 = 0$ and $i_2 = 2\sin 4t$ A, the voltage v_1 is

(A) $24\cos 4t$ V (B) $-24\cos 4t$ V

(C) $1.5\cos 4t$ V (D) $-1.5\cos 4t$ V

4. If $i_1 = e^{-2t}$ V and $i_2 = 0$, the voltage v_2 is

(A) $-6e^{-2t}$ V (B) $6e^{-2t}$ V

(C) $1.5e^{-2t}$ V (D) $-1.5e^{-2t}$ V

Statement for Q.5-6:

Consider the circuit shown in fig. P19.5-6

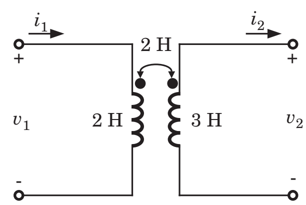

Fig. P1.9.5-6

5. If current $i_1 = 3\cos 4t$ A and $i_2 = 0$, then voltage v_1 and v_2 are

(A) $v_1 = -24\sin 4t$ V, $v_2 = -24\sin 4t$ V

(B) $v_1 = 24\sin 4t$ V, $v_2 = -36\sin 4t$ V

(C) $v_1 = 1.5\sin 4t$ V, $v_2 = \sin 4t$ V

(D) $v_1 = -1.5\sin 4t$ V, $v_2 = -\sin 4t$ V

6. If current $i_1 = 0$ and $i_2 = 4\sin 3t$ A, then voltage v_1 and v_2 are

(A) $v_1 = 24\cos 3t$ V, $v_2 = 36\cos 3t$ V

(B) $v_1 = 24\cos 3t$ V, $v_2 = -36\cos 3t$ V

(C) $v_1 = -24\cos 3t$ V, $v_2 = 36\cos 3t$ V

(D) $v_1 = -24\cos 3t$ V, $v_2 = -36\cos 3t$ V

Statement for Q.7-8:

In the circuit shown in fig. P1.9.7-8, $i_1 = 3\cos 3t$ A and $i_2 = 4\sin 3t$ A.

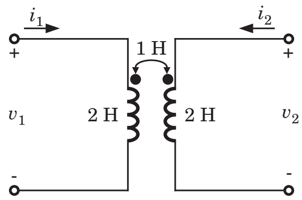

Fig. P1.9.7-8

7. v_1 = ?

(A) $6(-2\cos t + 3\sin t)$ V (B) $6(2\cos t + 3\sin t)$ V

(C) $-6(2\cos t + 3\sin t)$ V (D) $6(2\cos t - 3\sin t)$ V

8. v_2 = ?

(A) $3(8\cos 3t - 3\sin t)$ V (B) $6(2\cos t + 3\sin t)$ V

(C) $3(8\cos 3t + 3\sin 3t)$ V (D) $6(2\cos t - 3\sin t)$ V

Statement for Q.9-10:

In the circuit shown in fig. P1.9.9-10, $i_1 = 5\sin 3t$ A and $i_2 = 3\cos 3t$ A

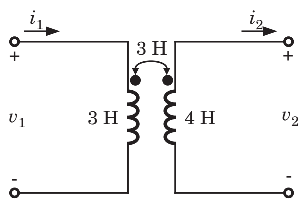

Fig. P1.9.9-10

9. v_1 =?

(A) $9(5\cos 3t + 3\sin 3t)$ V (B) $9(5\cos 3t - 3\sin 3t)$ V

(C) $9(4\cos 3t + 5\sin 3t)$ V (D) $9(5\cos 3t - 3\sin 3t)$ V

10. v_2 = ?

(A) $9(-4\sin 3t + 5\cos 3t)$ V (B) $9(4\sin 3t - 5\cos 3t)$ V

(C) $9(-4\sin 3t - 5\cos 3t)$ V (D) $9(4\sin 3t + 5\cos 3t)$ V

11. In the circuit shown in fig. P1.9.11 if current $i_1 = 5\cos(500t - 20°)$ mA and $i_2 = 20\cos(500t - 20°)$ mA, the total energy stored in system at $t = 0$ is

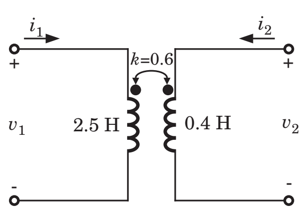

Fig. P1.9.11

(A) 151.14 μJ (B) 45.24 μJ

(C) 249.44 μJ (D) 143.46 μJ

12. L_{eq} = ?

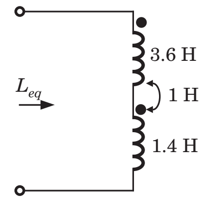

Fig. P1.9.12

(A) 4 H (B) 6 H

(C) 7 H (D) 0 H

13. L_{eq} = ?

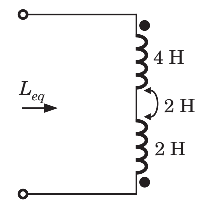

Fig. P1.9.13

(A) 2 H (B) 4 H

(C) 6 H (D) 8 H

14. L_{eq} = ?

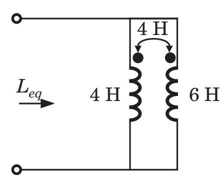

Fig. P1.9.14

(A) 8 H (B) 6 H

(C) 4 H (D) 2 H

15. L_{eq} = ?

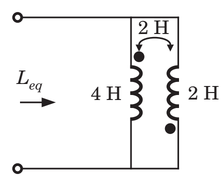

Fig. P1.9.15

(A) 0.4 H (B) 2 H

(C) 1.2 H (D) 6 H

16. The equivalent inductance of a pair of a coupled inductor in various configuration are

(a) 7 H after series adding connection

(b) 1.8 H after series opposing connection

(c) 0.5 H after parallel connection with dotted terminal connected together.

The value of L_1, L_2 and M are

(A) 3 H, 1.6 H, 1.2 H (B) 1.6 H, 3 H, 1.4 H

(C) 3.7 H, 0.7 H, 1.3 H (D) 2 H, 3 H, 3 H

17. L_{eq} = ?

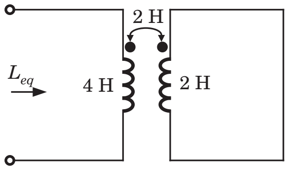

Fig. P1.9.17

(A) 0.2 H (B) 1 H

(C) 0.4 H (D) 2 H

18. L_{eq} = ?

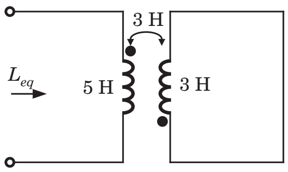

Fig. P1.9.18

(A) 1 H (B) 2 H

(C) 3 H (D) 4 H

19. In the network of fig. P1.9.19 following terminal are connected together

(i) none (ii) A to B

(iii) B to C (iv) A to C

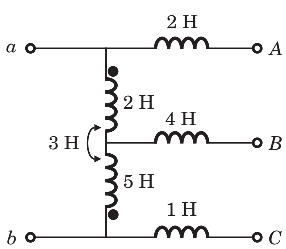

Fig. P1.9.19

The correct match for equivalent induction seen at terminal $a-b$ is

	(i)	(ii)	(iii)	(iv)
(A)	1 H	0.875 H	0.6 H	0.75 H
(B)	13 H	0.875 H	0.6 H	0.75 H
(C)	13 H	7.375 H	6.6 H	2.4375 H
(D)	1 H	7.375 H	6.6 H	2.4375 H

20. L_{eq} = ?

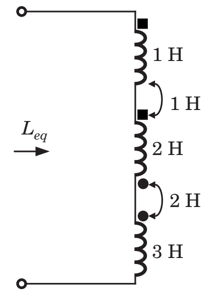

Fig. P1.9.20

(A) 1 H (B) 2 H

(C) 3 H (D) 4 H

21. L_{eq} = ?

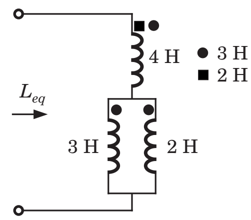

Fig. P1.9.21

(A) $\frac{41}{5}$ H (B) $\frac{49}{5}$ H

(C) $\frac{51}{5}$ H (D) $\frac{39}{5}$ H

Statement for Q.22-24:

Consider the circuit shown in fig. P1.9.22–24.

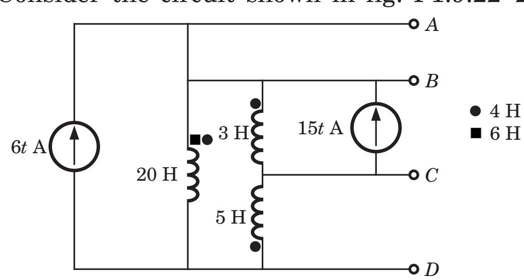

Fig. P1.9.22–24

22. The voltage V_{AG} of terminal AD is

(A) 60 V (B) –60 V

(C) 180 V (D) 240 V

23. The voltage v_{BG} of terminal BD is

(A) 45 V (B) 33 V

(C) 69 V (D) 105 V

24. The voltage v_{CG} of terminal CD is

(A) 30 V (B) 0 V

(C) –36 V (D) 36 V

33. In the circuit of fig. P1.9.33 the $\omega = 2$ rad/s. The resonance occurs when C is

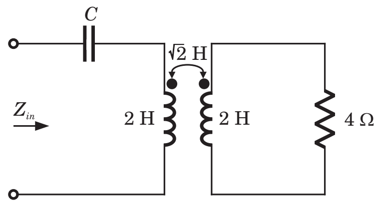

Fig. P1.9.33

(A) 1 F
(B) $\frac{1}{2}$ F
(C) $\frac{1}{3}$ F
(D) $\frac{1}{6}$ F

34. In the circuit of fig. P1.9.34, the voltage gain is zero at $\omega = 333.33$ rad/s. The value of C is

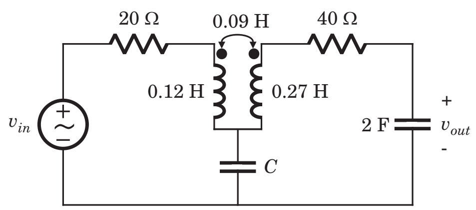

Fig. P1.9.34

(A) 100 μF
(B) 75 μF
(C) 50 μF
(D) 25 μF

35. In the circuit of fig. P1.9.35 at $\omega = 333.33$ rad/s, the voltage gain v_{out}/v_{in} is zero. The value of C is

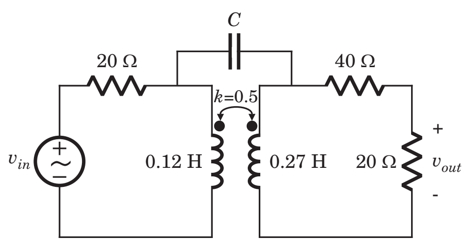

Fig. P1.9.35

(A) 3.33 mF
(B) 33.33 mF
(C) 3.33 μF
(D) 33.33 μF

36. The Thevenin equivalent at terminal ab for the network shown in fig. P1.9.36 is

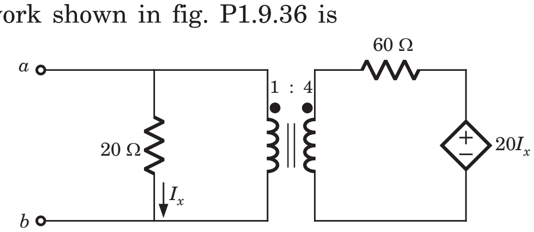

Fig. P1.9.36

(A) 6 V, 10 Ω
(B) 6 V, 4 Ω
(C) 0 V, 4 Ω
(D) 0 V, 10 Ω

37. In the circuit of fig. P1.9.37 the maximum power delivered to R_L is

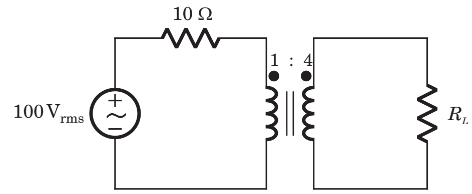

Fig. P1.9.37

(A) 250 W
(B) 200 W
(C) 150 W
(D) 100 W

38. The average power delivered to the 8 Ω load in the circuit of fig. P1.9.38 is

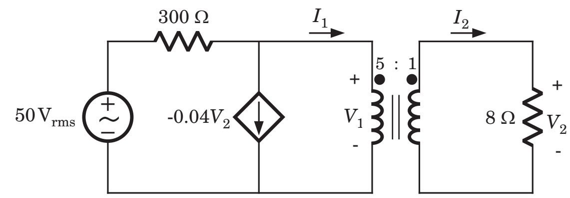

Fig. P1.9.38

(A) 8 W
(B) 1.25 kW
(C) 625 kW
(D) 2.50 kW

39. In the circuit of fig. P1.9.39 the ideal source supplies 1000 W, half of which is delivered to the 100 Ω load. The value of a and b are

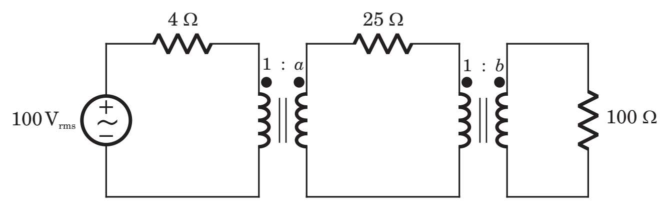

Fig. P1.9.39

(A) 6, 0.47
(B) 5, 0.89
(C) 0.89, 5
(D) 0.47, 6

40. $I_2 = ?$

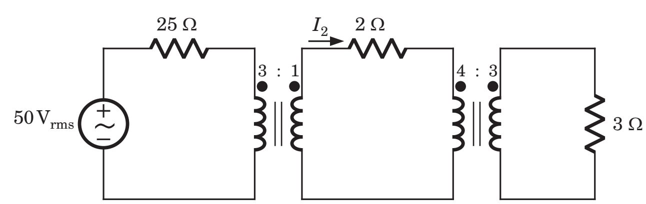

Fig. P1.9.40

(A) 1.65 A_{rms}
(B) 0.18 A_{rms}
(C) 0.66 A_{rms}
(D) 5.90 A_{rms}

41. $V_2 = ?$

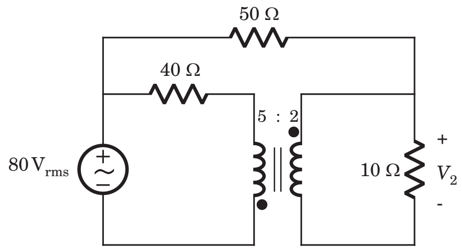

Fig. P1.9.41

(A) –12.31 V (B) 12.31 V

(C) –9.231 V (D) 9.231 V

42. The power being dissipated in 400 Ω resistor is

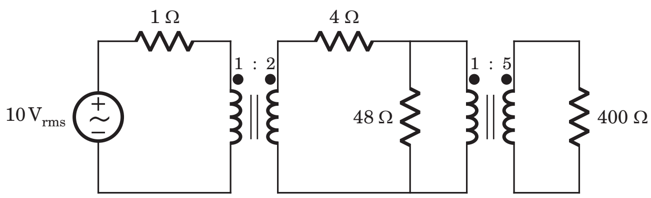

Fig. P1.9.42

(A) 3 W (B) 6 W

(C) 9 W (D) 12 W

43. $I_x = ?$

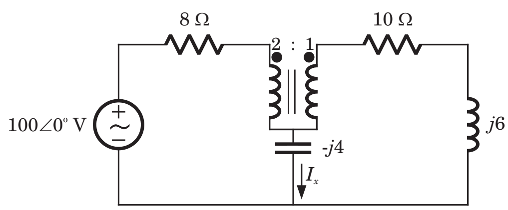

Fig. P1.9.43

(A) 1.921∠57.4° A (B) 2.931∠59.4° A

(C) 1.68∠43.6° A (D) 1.79∠43.6° A

44. $Z_{in} = ?$

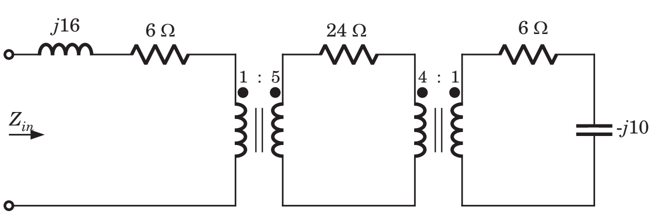

Fig. P1.9.44

(A) 46.3 + j6.8 Ω (B) 432.1 + j0.96 Ω

(C) 10.8 + j9.6 Ω (D) 615.4 + j0.38 Ω

****

SOLUTIONS

1. (B) $v_1 = 2\frac{di_1}{dt} + 1\frac{di_2}{dt} = 2\frac{di_1}{dt} = 16\cos 2t$ V

2. (C) $v_2 = (1)\frac{di_2}{dt} + (1)\frac{di_1}{dt} = \frac{di_1}{dt} = 8\cos 2t$ V

3. (B) $v_1 = 3\frac{di_1}{dt} - 3\frac{di_2}{dt} = -3\frac{di_2}{dt} = -24\cos 4t$ V

4. (C) $v_2 = 4\frac{di_2}{dt} - 3\frac{di_1}{dt} = -3\frac{di_1}{dt} = 6e^{-2t}$ V

5. (A) $v_1 = 2\frac{di_1}{dt} - 2\frac{di_2}{dt} = 2\frac{di_1}{dt} = -24\sin 4t$ V

$v_2 = -3\frac{di_2}{dt} + 2\frac{di_1}{dt} = 2\frac{di_1}{dt} = -24\sin 4t$ V

6. (D) $v_1 = 2\frac{di_1}{dt} - 2\frac{di_2}{dt} = -2\frac{di_2}{dt} = -24\cos 3t$ V

$v_2 = 3\frac{di_2}{dt} + 2\frac{di_1}{dt} = -3\frac{di_2}{dt} = -36\cos 3t$ V

7. (A) $v_1 = 2\frac{di_1}{dt} + 1\frac{di_2}{dt}$

$= -18\sin t + 12\cos t = 6(2\cos t - 3\sin t)$ V

8. (A) $v_2 = 2\frac{di_2}{dt} + 1\frac{di_1}{dt}$

$= 24\cos 3t - 9\sin 3t = 3(8\cos 3t - 3\sin 3t)$ V

9. (A) $v_1 = 3\frac{di_1}{dt} - 3\frac{di_2}{dt}$

$= 45\cos 3t + 27\sin 3t = 9(5\cos 3t + 3\sin 3t)$ V

10. (D) $v_2 = -4\frac{di_2}{dt} + 3\frac{di_1}{dt}$

$= 36\sin 3t + 45\cos 3t = 9(4\sin 3t + 5\cos 3t)$ V

11. (A) $W = \frac{1}{2}L_1 i_1^2 + \frac{1}{2}L_2 i_2^2 + M i_1 i_2$

At $t = 0$, $i_1 = 4\cos(-20°) = 4.7$ mA

$i_2 = 20\cos(-20°) = 18.8$ mA ,

$M = 0.6\sqrt{2.5 \times 0.4} = 0.6$

$W = \frac{1}{2}(2.5)(4.7)^2 + \frac{1}{2}(0.4)(18.8)^2 + 0.6(4.7)(18.8)$

$= 151.3$ μJ

12. (C) $L_{eq} = L_1 + L_2 + 2M = 7$ H

13. (A) $L_{eq} = L_1 + L_2 - 2M = 4 + 2 - 2 \times 2 = 2$ H

14. (C) $L_{eq} = \dfrac{L_1 L_2 - M^2}{L_1 + L_2 - 2M} = \dfrac{24 - 16}{6 + 4 - 8} = 4$ H

15. (A) $L_{eq} = \dfrac{L_1 L_2 - M^2}{L_1 + L_2 + 2M} = \dfrac{8 - 4}{6 + 4} = 0.4$ H

16. (C) $L_1 + L_2 + 2M = 7, \; L_1 + L_2 - 2M = 1.8$

$\Rightarrow \quad L_1 + L_2 = 4.4, \; M = 1.3$

$\dfrac{L_1 L_2 - M^2}{L_1 + L_2 - 2M} = 0.5, \; L_1 L_2 - 1.3^2 = 0.5 \times 1.8$

$L_1 L_2 = 2.59, \; (L_1 - L_2)^2 = 4.4^2 - 4 \times 2.59 = 9$

$L_1 - L_2 = 3, \; L_1 = 3.7, \; L_2 = 0.7$

17. (D) $L_{eq} = L_1 - \dfrac{M^2}{L_2} = 4 - \dfrac{4}{2} = 2$ H

18. (B) $L_{eq} = L_1 - \dfrac{M^2}{L_2} = 5 - \dfrac{9}{3} = 2$ H

19. (A)

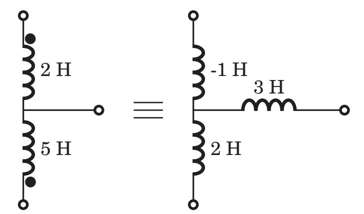

Fig. S.1.9.19

20. (D) $V_{L1} = 1sI + 1sI = 2sI$

$V_{L2} = 2sI + 1sI - 2sI = sI,$

$V_{L3} = 3sI - 2sI = sI$

$V_L = V_{L1} + V_{L2} + V_{L3} = 4sI \quad \Rightarrow \quad L_{eq} = 4$ H

21. (B) Let I_1 be the current through 4 H inductor and I_2 and I_3 be the current through 3 H, and 2 H inductor respectively

$I_1 = I_2 + I_3 \;, \; V_2 = V_3$

$3sI_2 + 3sI_1 = 2sI_3 + 2sI_1$

$\Rightarrow \quad 3I_2 + I_1 = 2I_3 \quad \Rightarrow \quad 4I_2 = I_3$

$\Rightarrow \quad I_2 = \dfrac{I_1}{5}, \; I_3 = \dfrac{4}{5} I_1$

$V = 4sI_1 + 3sI_2 + 2sI_3 + 3sI_2 + 3s\,I_1$

$= 7sI_1 + \dfrac{6s}{5} I_1 + \dfrac{2 \times 4s}{5} I_3$

$V = \dfrac{49}{5} sI_1 \;, \; L_{eq} = \dfrac{49}{5}$ H

22. (C) $v_{AG} = 20 \dfrac{d(6t)}{dt} + 4 \dfrac{d(15t)}{dt} = 180$ V

23. (B) $v_{BG} = 3 \dfrac{d(15t)}{dt} + 4 \dfrac{d\,6(t)}{dt} - 6 \dfrac{d\,(6t)}{dt} = 33$ V

24. (C) $v_{CG} = -6 \dfrac{d(6t)}{dt} = -36$ V

25. (B) $Z = Z_{11} + \dfrac{\omega^2 M^2}{Z_{22}}$

$= 4 + j\,(50)\left(\dfrac{1}{10}\right) + \dfrac{(50)^2 \left(\dfrac{1}{5}\right)^2}{5 + j\,(50)\dfrac{1}{2}}$

$= 4.77 + j\,1.15\,\Omega$

26. (B) $V_s = j\,(0.8)10(1.2\angle 0) - j\,(0.2)(10)(2\angle 0)$

$+[3 + j(0.5)(10)](1.2\angle 0 + 2\angle 0)$

$= 9.6 + j21.6 = 26.64\angle 66.04°$ V

27. (A) $[\,j(100\pi)\,(2) + 10]I_2 + j(100\pi)(0.4)\,(2\angle 0) = 0$

$\Rightarrow \quad I_2 = -0.4 - j0.0064,$

$V_o = 10I_2 = -4 - j0.064$

$= 4\angle -179.1°$

$\Rightarrow \quad v_o = 4\cos\,(100\pi t - 179.1°)$ V

28. (B) $30\angle 30° = I(-j6 + j8 - j4 + j12 - j4 + 10)$

$\Rightarrow \quad I = \dfrac{30\angle 30°}{(10 + j6)} = 2.57 - j0.043$

$V_o = I(\,j12 - j4 + 10)$

$= (2.57 - j0.043)(10 + 8j)$

$= 26.067 + j20.14 = 32.9\angle 37.7°$ V

29. (A)

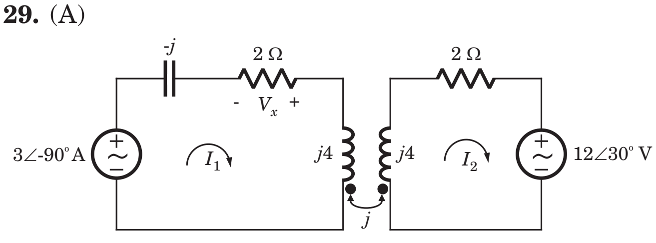

Fig. S1.9.29

$(-j + 2 + j4)I_1 - jI_2 = -j3$

$(\,j4 + 2)I_2 - jI_1 = -12\angle 30°$ V

$I_1 = -1.45 - j0.56,$

$V_x = -2\,I_1 = 2.9 + j1.12$

$= 3.11\angle 21.12°$ V

30. (D)

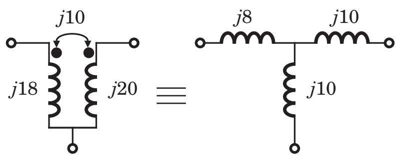

Fig. S.1.9.30

$$Z_{eq} = 10 + j8 + \frac{(j14)(j10 + 2 - j6)}{j14 + j10 + 2 - j6}$$

$$= 11.2 + j11.2\ \Omega$$

31. (C) $Z_{in} = (-j6) || (Z_o)$

$$Z_o = j20 + \frac{(12)^2}{(j30 + j5 - j2 + 4)} = 0.52 + j15.7$$

$$Z_{in} = \frac{(-j6)(0.52 + j15.7)}{(-j6 + 0.52 + j15.7)} = 0.20 - j9.7\ \Omega$$

32. (D) $M = k\sqrt{L_1 L_2}$, $\quad M^2 = 160 \times 10^{-12}$

$$Z_{in} = j\omega L_1 + \frac{\omega^2 M^2}{Z_L + j\omega L_2}$$

$$= j250 \times 10^3 \times 2 \times 10^{-6} + \frac{(250 \times 10^3)^2 \times 160 \times 10^{-12}}{2 + j10 + j \times 250 \times 10^3 \times 80 \times 10^{-6}}$$

$$Z_{in} = 0.02 + j0.17\ \Omega$$

33. (D)

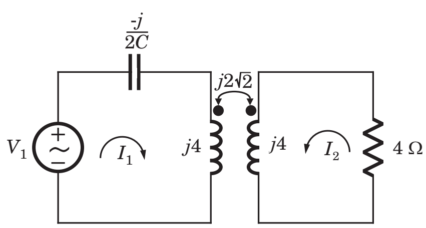

Fig. S.1.9.33

$$V_1 = -\frac{jI_1}{2C} + j4I_1 + j2\sqrt{2}\ I_2$$

$$0 = (4 + 4j)I_2 + j2\sqrt{2}I_1$$

$$\Rightarrow \quad I_2 = \frac{-j\sqrt{2}I_1}{2(1 + j)}$$

$$\frac{V_1}{I_1} = \frac{-j}{2C} + j4 + \frac{2}{1 + j} = \frac{-j + j8C + 2C - j2C}{2C}$$

$$Z_{in} = \frac{-j + j8C + 2C - j2C}{2C}$$

$$\text{Im}(Z_{in}) = 0 \quad \Rightarrow \quad -j + j8C - j2C = 0$$

$$\Rightarrow \quad C = \frac{1}{6}$$

34. (A) $j30 - \dfrac{3j}{1000C} = 0,\ C = 100\ \mu\text{F}$

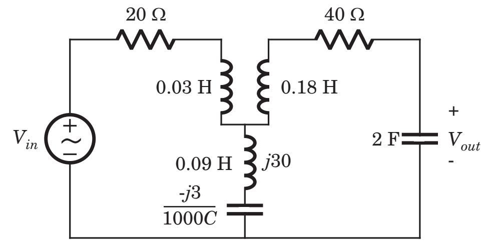

Fig. P1.9.34

35. (D) The π equivalent circuit of coupled coil is shown in fig. S1.9.35

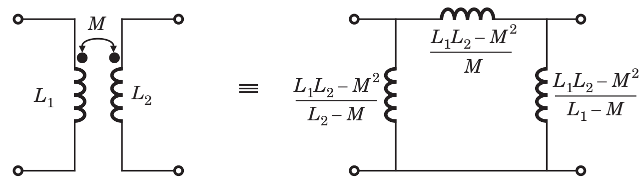

Fig. S1.9.35

$$\frac{L_1 L_2 - M^2}{M} = \frac{\sqrt{L_1 L_2}(1 - k^2)}{k} = \frac{\sqrt{0.12 \times 0.27}(1.0.5^2)}{0.5} = 0.27$$

Output is zero if $\dfrac{-j}{0.27\omega} + jC\omega = 0$

$$C = \frac{1}{0.27\omega^2} = 33.33\ \mu\text{F}$$

36. (C) Applying 1 V test source at ab terminal,

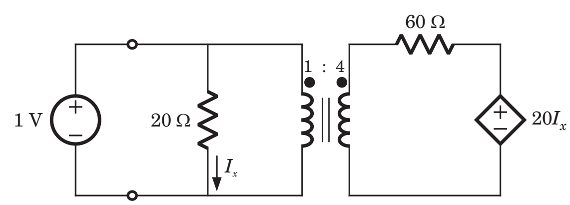

Fig. S1.9.36

$$V_{ab} = 1\text{ V},\ I_x = \frac{1}{20} = 0.05\ \text{ A},\ V_2 = 4\ \text{ V},$$

$$4 = 60\ I_2 + 20 \times 0.05 \quad \Rightarrow \quad I_2 = 0.05\ \text{ A}$$

$$I_{in} = I_x + I_1 = I_x + 4I_2 = 0.25\ \text{ A}$$

$$R_{TH} = \frac{1}{I_{in}} = 4\ \Omega\ , \qquad V_{TH} = 0$$

37. (A) Impedance seen by $R_L = 10 \times 4^2 = 160\ \Omega$

For maximum power $R_L = 160\ \Omega,\ Z_o = 10\ \Omega$

$$P_{Lmax} = \left(\frac{100}{10 + 10}\right)^2 \times 10 = 250\ \text{ W}$$

38. (B) $I_2 = \dfrac{V_2}{8}$, $I_1 = \dfrac{I_2}{5} = \dfrac{V_2}{40}$, $V_1 = 5V_2$